DECLARATION

I,Noboru YOSHIDA, of SHIGA INTERNATIONAL PATENT OFFICE, 2-3-1, Yaesu, Chuo-ku, Tokyo, Japan, understand both English and Japanese, am the translator of the English document attached, and do hereby declare and state that the attached English document contains an accurate translation of the official certified copy of Japanese Patent Application No. 2000-101069 and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

This 9 th day of April, 2004

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(Title of the Document)	Patent Application
(Docket Number)	J81311A1
(Filing Date)	April 3, 2000
(Destination)	Commissioner, Patent Office
(International Classification)	G05F 7/00
	F15D 1/00
	F63D 1/34
(Title of Invention)	FRICTION RESISTANCE SHIP AND METHOD FOR REDUCING FRICTIONAL RESISTANCE OF SHIP BODY
(Number of Claims)	4

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(Official Fees)

(Docket Number)	008707
(Amount of Payment)	¥21,000

(List of Documents Submitted)

(Item)	Specification	1
(Item)	Drawing	1
(Item)	Abstract	1

(General Power of Attorney Number) 9001603

[Document Type] SPECIFICATION

[Title of the Invention] METHOD FOR REDUCING FRICTIONAL RESISTANCE OF SHIP BODY, AND FRICTION REDUCING SHIP

[Claims]

[Claim 1] A method for reducing frictional resistance of a ship body by ejecting gas bubbles on a submerged surface of the ship body, comprising:

creating in the water a negative pressure region, having a pressure lower than a pressure in a gaseous space, resulting from the ship body cruising through the water, directing a gas from the gaseous space to the negative pressure region in the water, and forming a flow of water having locally large vortices.

[Claim 2] A friction reducing ship that reduces frictional resistance of a ship body by ejecting gas bubbles on a submerged surface of the ship body, comprising:

a negative pressure forming section for creating a negative pressure region in the water having a lower pressure relative to a gaseous space;

a fluid passage for directing a gas from the gaseous space to the negative pressure region in the water; and

a detachment promotion section for forming a flow of water having locally large vortices.

[Claim 3] A friction reducing ship according to claim 2, wherein the negative pressure forming section comprises a wing protruding into the water from the submerged surface of the ship body; a strut for supporting the wing; and a fluid guiding body disposed on the ship body corresponding to the wing.

[Claim 4] A friction reducing ship according to claim 3, wherein the detachment promotion section is formed by said wing which is formed on the ship body so as to have

a convex shape, and said fluid guiding body which is formed so as to follow a shape of the wing.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

This invention relates to a method of reducing the frictional resistance of a ship body and to a friction reducing ship, and in particular, to improving the total energy efficiency by efficiently ejecting bubbles into the water.

[0002]

[Prior Art]

Conventionally, methods have been proposed for the purpose of reducing energy consumption when a vessel or the like is cruising, in which bubbles are ejected into the water and frictional resistance between a ship body and the water is reduced by interposing a multitude of bubbles in the vicinity of the surface (submerged surface) of the outer hull of the ship body.

[0003]

Techniques of generating bubbles in the water are proposed in Japanese Unexamined Patent Applications, First Publication Nos. Sho 50-83992, Sho 53-136289, Sho 60-139586, Sho 61-71290, and in Japanese Unexamined Utility Model Applications, First Publication Nos. Sho 61-39691 and Sho 61-128185.

[0004]

In these techniques, methods for generating bubbles in the water rely on equipment such as pumps and blowers to eject pressurized gas into the water through a plurality of holes or porous plates provided on the ship body.

[0005]

[Problems to be Solved by the Invention]

However, the method of ejecting pressurized gas into the water presents a problem in that energy is needed in operating the pressurizing equipment so that it results in a loss of part of the energy savings achieved by reducing the frictional resistance. Especially, if the gas is ejected into the water from relatively deep locations below the surface such as at the bottom surface of large capacity vessels, it is necessary to pressurize the gas to a higher pressure relative to the water pressure (static pressure), thus resulting in expending a large amount of energy. Also, when providing pressurizing equipment in the ship body, high costs such as installation and operating costs are generated.

[0006]

This invention is provided in view of the above circumstances, and the objectives of the invention are as follows.

(1) To effectively reduce the energy consumption during cruising by lowering the frictional resistance at a lower energy consumption.

(2) To mix bubbles into the water efficiently to achieve effective reduction in frictional resistance.

(3) To reduce the cost of constructing the ship body.

[0007]

[Means for Solving the Problems]

In order to solve the above-mentioned problems, the invention according to claim 1 adopts, in a method for reducing the frictional resistance of a ship body by ejecting bubbles on a submerged surface of the ship body, a technique of forming a negative pressure region in the water having a lower pressure relative to a gaseous space resulting

from cruising of the ship body through the water, directing a gas from the gaseous space to the negative pressure region in the water, and forming a flow of water having locally large vortices.

Furthermore, the invention according to claim 2 adopts, in a friction reducing ship which reduces the frictional resistance of a ship body by ejecting bubbles on a submerged surface of the ship body, a technique of providing a negative pressure forming section for forming a negative pressure region in the water having a lower pressure relative to a gaseous space, a fluid passage for directing a gas from the gaseous space to the negative pressure region in the water, and a detachment promotion section for forming a flow of water having locally large vortices.

Moreover, the invention according to claim 3 adopts, in the friction reducing ship according to claim 2, a technique in which the negative pressure forming section comprises a wing protruding into the water from the submerged surface of the ship body, a strut for supporting the wing, and a fluid guiding body disposed on the ship body corresponding to the wing.

Furthermore, the invention according to claim 4 adopts, in the friction reducing ship according to claim 3, a technique in which the detachment promotion section is formed by the wing which is formed on the ship body so as to have a convex shape, and the fluid guiding body which is formed so as to follow a shape of the wing.

[0008]

[Operation of the Invention]

In general, when a pressure gradient is formed in a fluid environment, the fluid is subjected to a force acting from a higher pressure side to a lower pressure side (pressure gradient force) to induce the fluid to flow. Therefore, by creating a negative pressure

region in the water having a lower pressure with respect to the pressure in a gaseous space and directing a gas in the gaseous space to the negative pressure region in the water, it becomes possible to eject the gas into the water at a certain depth using the pressure gradient force.

[0009]

Fig. 2 schematically shows a friction reducing ship having a negative pressure forming section for creating a negative pressure region in the water. When a ship body 1 is moving at a given cruising speed Vs, a flow of water 2 relative to the ship body 1 is formed. If the fluid passage of water is narrowed by a negative pressure forming section 3, for example, the flow velocity of the water increases, and the hydrostatic pressure Pwa decreases locally (Bernoulli's principle). Designating the water flow velocity by Vwa, the pressure in the gaseous space (atmospheric pressure) by Pa, the water density by ρ, gravitational acceleration by g, and the water depth by Hwa, then the hydrostatic pressure Pwa is given by the following expression:

$$Pwa = Pa + \rho \cdot g \cdot Hwa - \rho \cdot (Vwa^2 - Vs^2)/2 \qquad (1)$$

As can be seen clearly from equation (1), when the water flow velocity Vwa satisfies the following equation, a negative pressure region 4 having a lower pressure relative to the atmospheric pressure Pa is formed.

$$\rho \cdot g \cdot Hwa - (Vwa^2 - Vs^2)/2 < 0 \qquad (2)$$

[0010]

When the negative pressure region 4 is formed, the gas is made to flow inside a fluid passage 5 by the pressure gradient force and is ejected into the water.

[0011]

When the gas is ejected into the water by forming the negative pressure region 4

(negative pressure method), because there is no need to pressurize the gas, the amount of energy expended in ejecting the gas into the water is less compared with the conventional pressure method.

[0012]

Also, by mixing the gas ejected into the water as bubbles 6, a plurality of the bubbles 6 are allowed to intervene at the submerged surface of the ship body 1 to reduce the frictional resistance of the ship body.

[0013]

However, the bubbles 6 in the water are acted on by various forces due to the flow of water. Examples of such forces are shown in Table 1.

[0014]

[Table 1]

[0015]

For example, as shown in Fig. 2, it is considered that, when the negative pressure forming section 3 protrudes from the bottom of the ship, the gas flowing inside the fluid passage 5 reaches a boundary surface 7 (gas/liquid interface) between the gas and the liquid (water), and is then transferred into the water as the bubbles 6 as a result of the pressure gradient force exerted by the negative pressure region 4 as well as a lift force which will be explained later, and then flows by riding on the water due to a resistance force (viscous force).

[0016]

The lift force is generated when the flow of water 2 around the bubbles 6 has vortices, and the direction of this force is in the opposite direction of a vector obtained by the cross product of a vorticity vector of liquid ω and a gas-liquid relative velocity vector

us. The magnitude is proportional to the volume of bubbles Av and the density of liquid ρ. That is, the lift force Lf is expressed by the following equation.

$$Lf = -\rho \cdot Av \cdot (us \times \omega) \qquad (3)$$

This is Auton's inertial lift force. When the Reynold's number is low, a Saffman lift force acts so that it is proportional to the vortex raised to the power of 1/2. Here, the direction of action is the same in both cases.

[0017]

In the boundary layer at the bottom of the ship, flows having vortices are concentrated near the surface of the ship body outer hull in general, so that each of the above-described vectors is directed as shown in Fig. 3. As can be understood from Fig. 3, the lift force Lf at the bottom of the ship acts in the direction of separation from the ship body outer hull, that is, in the direction of detachment of the bubbles 6 from the gas/liquid interface 7 into the water.

[0018]

However, depending on the shape of the negative pressure forming section, a relatively large force (resistance force) can sometimes act on the bubbles in a direction which forces them to return to the gas/liquid interface.

[0019]

For example, when the water flows along the negative pressure forming section 3 shown in Fig. 2, an additional inertial force which will be explained below and the pressure gradient force act as the resistance force on the bubbles 6.

[0020]

The additional inertial force is the inertial force due to the added mass of bubbles placed in the liquid (water), and if the density difference between the gas and liquid is

assumed to be 1/800, then compared with the inertial force acting on the mass of the gas itself inside the bubbles, it is 400 times the size. Also, compared with the inertial force of the water, the inertial force of the bubbles + the additional inertial force is 1/2 the size. Based on this, when the same external force acts, bubbles will be generated at three times the acceleration of the water, $1 + 1/(1/2) = 3$ (assuming the maximum value by neglecting the resistance force).

[0021]

That is, as shown in Fig. 4, for the case when the bubbles 6 and the water flow along a curved surface of a body 8, when the flow of water 2 changes to a downward direction at a concave section PA1, the bubbles 6 descend at three times the acceleration of the water. Also, when the flow of water 2 changes to an upward direction at a convex section PA2, the bubbles 6 ascend at three times the acceleration of water.

[0022]

Therefore, for the case when the water flows along the negative pressure forming section 3 in Fig. 2 described above, due to the curvature of the apex section of the negative pressure forming section 3 (convex section), as the flow of water 2 changes to an upward direction at the negative pressure region 4, the additional inertial force acts in the direction of returning the bubbles 6 back to the gas/liquid interface 7.

[0023]

Also, in the case shown in Fig. 2, because the negative pressure region 4 is at a lower pressure compared with other regions in the water, the bubbles 6 residing in the negative pressure region 4 are acted on by the pressure gradient force in the direction of returning them to the gas/liquid interface 7.

[0024]

Then, when such a force (resistance force) in the direction of returning to the gas/liquid interface strongly acts on the bubbles, it becomes difficult for the bubbles to detach from the gas/liquid interface in the water, the amount of bubbles to be mixed in the water is suppressed, and there is a danger that the frictional resistance of the ship body may not be reduced effectively.

[0025]

Therefore, the flow of water is formed so that the bubbles move from the gas/liquid interface into the water so as to decrease the force which resists detachment of the bubbles. Therefore, the bubbles can easily detach from the gas/liquid interface, and the amount of bubbles to be mixed in the water increases.

[0026]

That is, by forming a flow of water having locally large vortices, the lift force acts in the direction of detachment, and detachment of the bubbles from the gas/liquid interface is promoted.

[0027]

[Embodiments of the Invention]

Below, an embodiment will be described with reference to the figures, wherein the method of reducing frictional resistance of a ship body and the friction reducing ship according to this invention are applied to a bulk ship such as a tanker or freighter. In Fig. 5, reference symbol M is a friction reducing ship, 10 is a ship body, 11 is a bubble generation apparatus, 12 is a ship body outer hull (submerged surface), 13 is a screw, 14 is a rudder, and 15 is the water surface (waterline).

[0028]

A VLCC (Very Large Crude Oil Carrier), for example, corresponds to the bulk ship

as the friction reducing ship M. In comparison with other types of vessels, the surface area on the bottom of the ship is formed to be relatively large in comparison with the side of the ship in the ship body outer hull 12 (submerged surface) which is beneath the waterline 15. Moreover, the bubble generation apparatus 11 is disposed at the front of the ship body 10.

[0029]

As shown in Fig. 5(b), the bubble generation apparatus 11 is constituted by a negative pressure forming section 20 disposed on the submerged surface 12 of the ship body 10, and a fluid passage 21 which passes through the ship body 10 and in which an internal space is open above and below the waterline 15.

[0030]

The negative pressure forming section 20 forms a negative pressure region having a lower pressure relative to the gaseous space (atmosphere) during cruising at a certain cruising speed Vs by utilizing the relative flow of the water with respect to the ship body 10 during cruising. In this case, the negative pressure forming section 20 also functions as a detachment promotion section which promotes detachment of the gas bubbles from the gas/liquid interface as will be described later, and is constructed in such a way as to increase the relative speed of the water at the bottom of the ship in a specific location as well as to form a curved flow of water which is convex upward in the vertical direction.

[0031]

Details of the negative pressure forming section 20 will be explained next. As shown in Fig. 6, the negative pressure forming section 20 is disposed so as to protrude into the water from the submerged surface of the ship body, and is provided with a wing 30 disposed roughly parallel to the submerged surface 12 at a given distance, struts 31, 32

disposed between the wing 30 and the ship body outer hull 12 for supporting the wing 30, and a fluid guiding body 33 disposed on the ship body corresponding to the wing 30 (inner side of the ship body in this embodiment).

[0032]

Various wing shapes such as a NACA wing type, ogival wing type, etc., can be applied as the shape of the wing 30, and the shape is chosen in accordance with the shape of the ship body and its cruising speed. In this case, the wing 30 is formed so as to be convex toward the ship body. Also, the wing 30 is disposed in such a way that a front edge 30a and rear edge 30b are oriented in the traveling direction Dve of the ship body, wing surfaces 30c, 30d are oriented in the up- and down-directions, and further, it is disposed such that a lift force acts upward on the wing 30 during cruising (such that, during cruising, the flow velocity at the wing surface 30c which is directed upward is large in comparison with the flow velocity at the wing surface 30d which is directed downward).

[0033]

The horizontal cross sectional shape of the struts 31, 32 is chosen so as to offer low resistance to the flow of water, a wing type shape for example, and has a specific height Hst for specifying the spacing between the wing 30 and the submerged surface 12. Further, it is attached so that one end surface abuts the ship body outer hull 12 and the other end surface abuts the wing 30.

[0034]

The fluid guiding body 33 is provided for guiding the flow of water to form a curved shape (an arc shape) during cruising, is formed in a box type having one surface open, and is fixed so that an open end 33a abuts the ship body outer hull 12 and covers an

opening 12a provided on the ship body outer hull 12 from the inner side of the ship body 10. Also, the fluid guiding body 33 is formed to conform to the shape of the wing 30, and has a curved surface 33b, which is parallel to the width direction of the ship body 10 (direction roughly perpendicular to the traveling direction Dve of the ship body 10 within a horizontal plane) and the height from the ship body outer hull 12 varies in a convex shape along the traveling direction Dve of the ship body 10 (that is, curves upward in a convex shape in the vertical direction). Further, a discharge opening 33c comprising a through-hole is provided near the center of the curved surface 33b.

[0035]

By this means, as shown in Fig. 5(b), a curved water passage 34 which is convex upward in the vertical direction and serving as the detachment promotion section, is formed along the traveling direction Dve of the ship body.

[0036]

Also, the shape and positioning of each of the components of the negative pressure forming section 20 are designed by flow field analysis of CFD (computational fluid dynamics) so that the flow of water in the negative pressure forming section 20 during cruising conforms to a desired state. In this case, when the ship is cruising at a given ship velocity Vs, the flow of water in the vicinity of the negative pressure forming section 20 is set so as to satisfy the following conditions (a) to (d).

•Condition (a): The flow velocity of water (absolute value) in the water passage 34 is higher than the ship velocity Vs, and the average flow velocity Vwa in midsection 34b (refer to Fig. 5(b)) of the water passage 34 satisfies equation (2) described above, (where ρ in equation (2) is the density of seawater, and Hwa is the distance (water depth) from the waterline to the water passage 34).

•Condition (b): The flow velocity of water near the wing surface 30c is higher than that in the vicinity of the discharge opening 33c of the fluid guiding body 33.

•Condition (c): A flow of water directed downward from the discharge opening 33c is present.

•Condition (d): Locally large vortices are present in the flow of water in the water passage.

[0037]

In order to satisfy condition (a), the shape and positioning of each of the components of the negative pressure forming section 20 are determined such that, for example, the cross sectional areas of the flow passage in the inner side (front-section 34a, midsection 34b, rear section 34c) are small compared with the cross sectional area of the flow passage at the inlet opening of the water passage 34, and the cross sectional area of the flow passage in the midsection 34b is small compared with that in the front section 34a and the rear section 34c.

Also, in order to satisfy condition (b), the overall curvature of the wing surface 30c is set to be smaller (radius of curvature is larger) than that of the curved surface 33b of the fluid guiding body 33, for example.

Also, in order to satisfy condition (c), the curved surface 33b in the vicinity of the discharge opening 33c is made to have a curved surface which is convex upward, for example.

Further, in order to satisfy condition (d), the cross sectional area of the fluid passage and the shape of the water passage 34 are varied locally, for example.

[0038]

On the other hand, the fluid passage 21 comprises an inner space 36 of an air

induction pipe 35 which connects to the fluid guiding body 33 in the negative pressure forming section 20. That is, one end of the fluid passage 21 is open to the gaseous space (atmosphere) by way of an air intake opening 37 of the air induction pipe 35 while the other end is open to the water by way of the discharge opening 33c of the fluid guiding body 33.

[0039]

The air induction pipe (AIP) 35 is installed so as to pass through the ship body 10 and to connect to the fluid guiding body 33 in the negative pressure forming section 20, and the cross sectional area and the shape of the interior section are set so that a desired flow rate of the fluid can flow at a low pressure loss. Also, the air intake opening 37 is disposed at the front section of the deck of the ship body 10.

[0040]

Further, as the material of the negative pressure forming section 20 and the air induction pipe 35, those which provide a surface which is corrosion resistant primarily with respect to sea water and which is resistant to attachment of marine organisms, such as metals which have undergone some corrosion resistant treatment, or resins, etc., are preferably used.

[0041]

Also, the negative pressure forming section 20 may be provided such that one or more units are arranged according to the breadth of the bottom of the ship and the air induction pipes 35 are arranged accordingly.

[0042]

Next, a method of reducing the frictional resistance of a ship body by means of the friction reducing ship M having such a constitution will be explained with reference to

Fig. 1.

In the stationary state of the ship, water (seawater) ingresses into the fluid passage 21 to about the same level as that surrounding the ship body 10. When the ship body 10 begins to cruise using the thrust of the screw 13 (refer to Fig. 5), a flow of water 40 relative to the ship body 10 is formed as shown in Fig. 1(a).

[0043]

In the cruising state, at the bottom of the ship, water flows along the wing 30 of the negative pressure forming section 20, and due to the narrowing of the flow path in the curved water passage 34, the flow velocity of water flowing through the water passage 34 increases, and the static pressure is reduced locally.

[0044]

Then, when the cruising speed of the ship body 10 reaches a certain ship velocity Vs (standard cruising speed, for example), a negative pressure region 41, which is a region of low pressure relative to atmospheric pressure, is formed in the midsection 34b of the water passage 34 (due to condition (a) described above).

[0045]

In this case, compared with the pressure at the air intake opening 37, the pressure in the vicinity of the discharge opening 33c facing the negative pressure region 41 is low so that the fluid (seawater and air) inside the fluid passage 21 is subjected to a pressure gradient force Pf1 such that, after the seawater is discharged from the fluid passage 21, the air flowing in from the air intake opening 37 is ejected into the water by flowing through the fluid passage 21.

[0046]

Then, the gas ejected into the water becomes mixed in the water as air bubbles 42,

and the frictional resistance of the ship body 10 is reduced by the presence of numerous bubbles 42 intervening in the vicinity of the submerged surface 12 of the ship body 10.

[0047]

The energy required to eject the air into the water is primarily the energy for changing the position of the gas. This energy is obtained by varying the flow conditions of the water by means of the negative pressure forming section 20, and is less than the energy consumed in compressing and ejecting the gas into the water. For this reason, due to the reduction in the frictional resistance of the ship body 10, the energy consumption during cruising is effectively reduced.

[0048]

Further, in the formation of the negative pressure region 41, the shape and Reynolds number of the negative pressure forming section 20 are the primary governing factors, and disadvantages arising from the water depth are less likely to occur, so that the technology of this invention can be favorably applied to bulk ships.

[0049]

Also, the bubble generation apparatus 11 has a simple constitution, and a device for compressing gas is not required so that it is obvious that the construction cost of the ship body 10 is less.

[0050]

In this case, as shown in Fig. 1(b), the water passage 34 forms a curved flow which is convex upward so that water that has flowed through the discharge opening 33c descends by changing the direction of flow to the direction of separation from a gas/liquid interface 43 (due to condition (c)). At this time, the bubbles 42 move away from the discharge opening 33c at an acceleration larger than that of water. In other words, the

inertial force (additional inertial force) due to the additional mass acts on the bubbles 42 in the direction of detachment of the bubbles 42 from the gas/liquid interface 43 (detachment direction).

[0051]

Further, because the flow velocity of the water flowing in the vicinity of the wing surface 30c in the water passage 34 is larger than the flow velocity of the water flowing in the vicinity of the discharge opening 33c of the fluid guiding body 33 (due to condition (b)), the pressure at the negative pressure region 41 in the water becomes progressively lower, beginning at the gas/liquid interface 43 towards the water. For this reason, a pressure gradient force Pf2 acts on the bubbles 42 in the detachment direction.

[0052]

Also, because the cross sectional area (and shape) of the flow passage of the water passage 34 varies locally, the flow of water 40 in the water passage 34 exhibits locally large vortices (due to condition (d)). In this case, the flow of water 40 exhibits a large vortex in the midsection 34b of the water passage 34, where curvature of the flow curve is large. For this reason, the lift force Lf1 acts on the bubbles 42 in a downward direction (detachment direction) which is a direction opposite to the curvature of the flow curve.

[0053]

Then, due to such forces operating in the detachment direction (additional inertial force Af, pressure gradient force Pf2, and lift force Lf1), the forces that resist the bubbles 42 become smaller, resulting not only in promotion of detachment of the bubbles 42 from the gas/liquid interface 43, but also in reducing the energy required for ejecting air into the water.

That is, the water passage 34 serving as a detachment promotion section is formed

by the wing 30 and the fluid guiding body 33, and the water passage 34 forms a curved flow of water having local vortices, so that in addition to the lift force L1, the pressure gradient force Pf2, and additional inertial force Af are made to act, thereby promoting detachment of the bubbles 42 from the gas/liquid interface 43, and increasing the number of bubbles to be mixed in the water.

[0054]

Also, because the wing 30 is subjected to an upward lift force by the flow of water 40, the bow side of the ship body 10 is raised, for example, the submerged area of the ship body 10 is reduced, and it becomes easier to reduce the frictional resistance.

[0055]

The struts 31, 32 of the negative pressure forming section 20 serve to reduce the cross sectional area of the flow passage of the water passage 34, and also vary the flow curve, and therefore are advantageously at work in increasing the force acting in the detachment direction at the midsection 34b of the water passage 34 where the negative pressure region 41 is created.

[0056]

The amount of bubbles 42 created in the negative pressure region 41 is influenced by the saturation vapor pressure determined by the surrounding environmental conditions. That is, a portion of a gas, which is more that the amount of gas dissolved in the water, exists as bubbles in the water. Therefore, by promoting detachment of the bubbles 42 from the gas/liquid interface 43, fewer bubbles 42 accumulate near the gas/liquid interface 43, and a desired amount of bubbles 42 can be mixed in the water in a stable manner, to result in effectively and reliably reducing the frictional resistance.

[0057]

Here, the bubbles 42 mixed into the water are formed at a lower internal pressure than the static pressure resulting due to the water depth so that, when the bubbles 42 are moving through a constant water depth (for example, when the bubbles move along the bottom of the ship), a large water pressure acts on the bubbles 42 as they separate from the negative pressure region 41 so that the size of the bubbles 42 is gradually reduced. According to the results of research by the present applicants, it has been found that relatively smaller bubbles are preferable in reducing frictional resistance of the ship body. Therefore, for this reason as well, the bubbles generated by negative pressure are advantageously at work in reducing the frictional resistance.

[0058]

Fig. 7 shows another embodiment of the friction reducing ship according to this invention.

This friction reducing ship M2 is different from the ship described in the preceding embodiment in that the negative pressure forming section in the bubble generation apparatus is constituted so as to move vertically.

[0059]

A bubble generation apparatus 50 comprises: an outer tube 51 installed in the ship body in a fixed state; an inner tube 52 serving as an air induction pipe (AIP) detachably housed in the outer tube 51 so as to be freely movable in the axial direction (vertical direction); and a position adjusting section 53 for adjusting the position (height) in the axial direction of the inner tube 52 in relation to the outer tube 51.

[0060]

The inner tube 52 is inserted from an opening at the top end section of the outer tube 51 in such a way that a negative pressure forming section 54 disposed on one end of the

inner tube 52 is directed downward.

[0061]

The negative pressure forming section 54, as shown in Fig. 8, comprises: a plate member 61 disposed so as to block the end section of a pipe member 60; a wing 62 disposed roughly parallel to the plate member 61 with a given spacing; struts 63, 64 for supporting the wing 62; and a curved plate 66 disposed on the plate member 61 so as to cover an opening 65 serving as a discharge opening from the inside of the pipe member 60.

[0062]

These component parts form a water passage 67, serving as a curved detachment promotion section which is convex upward in the vertical direction, in the negative pressure forming section 20 along the traveling direction of the ship body.

[0063]

Also, the inner space of the inner tube 52, serving as a fluid passage 68, opens downward by way of a space 69, formed between the curved plate 66 and the plate member 61, and the discharge opening 65.

[0064]

Returning to Fig. 7, the position adjusting section 53 is used to adjust the protruding state (protrusion height) from the bottom of the ship of the negative pressure forming section 54, in accordance with the cruising state, and includes a drive section, not shown in the figures, such as a motor for moving the inner tube 52 to a certain location, a fixation section, not shown in the figures, for fixing the inner tube 52 at a certain location, and the like.

[0065]

The friction reducing ship M2 provided with the bubble generation apparatus 50 having such a constitution can vary the protrusion height of the negative pressure forming section 54 by means of the position adjusting section 53 in accordance with the cruising state, thereby appropriately suppressing an increase in resistance caused by the negative pressure forming section 54 as well as adjusting the flow of the water in the vicinity of the negative pressure forming section 54 to a desired state.

[0066]

For example, when the ship is stationary or moving at a low speed so that the friction reducing effects due to bubbles are minor, the negative pressure forming section 54 is disposed inside the ship body (inside the submerged surface), as shown in Fig. 9(a), so as to suppress an increase in resistance due to the negative pressure forming section 54.

[0067]

On the other hand, when the ship is cruising at a certain ship speed, the negative pressure forming section 54 protrudes into the water (downward) from the bottom of the ship, as shown in Figs. 9(b) and (c), and the frictional resistance of the ship body is reduced by the generation of bubbles 70 in the water.

[0068]

When the protrusion height of the negative pressure forming section 54 is varied, the flow rate per unit time of the water flowing in the water passage 67 of the negative pressure forming section 54 is altered, and the flow velocity of water in the water passage 67 is changed. Accordingly, the state of a negative pressure region 71 (static pressure and the like), the magnitude of the force in the detachment direction acting from the gas/liquid interface, and the like, are altered, and the amount of bubbles 70 to be mixed in the water is varied.

[0069]

That is, by altering the protrusion height of the negative pressure forming section 54, the pressure in the negative pressure region 71 and the flow of water 72 near the negative pressure region 71 are controlled to adjust the amount of bubbles 70 generated. Then, an effective reduction of frictional resistance is achieved by means of an appropriate amount of bubbles 70 in accordance with the ship speed.

[0070]

Further, during maintenance of the bubble generation apparatus 50, the inner tube 52 is removed from the outer tube 51, and the inner tube 52 as well as the inner wall surface of the outer tube 51 are cleaned in a well-equipped cleaning facility. Therefore, the labor involved in the maintenance of the bubble generation apparatus 50 is small.

[0071]

Also, the shapes and combination of each component shown in this embodiment are just examples, and various modifications within the scope of this invention based on design requirements are possible. For example, a variation such as described below can also be included.

[0072]

In the embodiment described above, the negative pressure forming section 20 has two functions of forming a negative pressure region in the water and forming a flow of water which generates a force in the detachment direction, and provides an advantage of enabling the efficient mixing of bubbles into the water within a small space. However, it is permissible to separate the function of forming a negative pressure region (negative pressure forming section) and the function of forming a flow of water to promote detachment (detachment promotion section) into two distinct means. By separating into

two distinct means, it becomes easier to control the amount of bubbles to be mixed into the water.

[0073]

Also, the shape of the wing of the negative pressure forming section is designed so as to suppress an increase in the resistance to the water. Therefore, the wing presented in the above embodiment is not limited to one in which the planar shape of the wing surface is a rectangular shape, and other shapes such as a triangle shaped wing surface are also acceptable.

[0074]

Also, in this embodiment, this invention is applied to a bulk ship, but it is not limited to such an application, and it is applicable to other ship types such as high-speed ships. The size, number and location of negative pressure forming sections are chosen suitably according to the shape of the ship body.

[0075]

[Effects of the Invention]

As described above, the following effects can be obtained by this invention.

According to the method of reducing frictional resistance of a ship body according to claim 1, by forming a negative pressure region in the water, use can be made of a pressure gradient force, gas can be ejected into the water at a lower energy consumption as compared with compressing the gas, and it is possible to carry out reduction in frictional resistance. Furthermore, by forming a flow of water having locally large vortices, use can be made of a lift force, detachment of bubbles from the boundary surface can be promoted, and it is possible to increase the amount of bubbles to be mixed into the water. Accordingly, it is possible to implement an effective reduction in frictional

resistance and reduce the energy consumption during cruising.

According to the friction reducing ship according to claim 2 through claim 4, by providing the negative pressure forming section, a negative pressure region can be formed in the water, use can be made of a pressure gradient force, gas can be ejected into the water at a lower energy consumption as compared with compressing the gas, and it is possible to carry out reduction in frictional resistance. Furthermore, due to the flow of water formed by the detachment promotion section, use can be made of a lift force, detachment of bubbles from the boundary surface can be promoted, and it is possible to facilitate increasing the amount of bubbles to be mixed into the water. Accordingly, it is possible to implement an effective reduction in frictional resistance and reduce the energy consumption during cruising. Moreover, a device for compressing gas is not required, and it is possible to easily reduce the construction cost of the ship body.

[Brief Description of the Drawings]

[Figure 1] This is a conceptual drawing showing an example of a method for reducing the frictional resistance of a ship body according to this invention.

[Figure 2] This is a conceptual drawing showing an example of a method for generating bubbles in the water.

[Figure 3] This is a schematic drawing showing forces applied to bubbles at the bottom of a ship.

[Figure 4] This is a schematic drawing showing the flowing state of water and bubbles along a curved surface.

[Figure 5] This is a structural diagram schematically showing an embodiment in which the method of reducing frictional resistance of a ship body according to this invention is applied to a vessel.

[Figure 6] This is a perspective view schematically showing the constitution of the negative pressure forming section shown in Figure 1.

[Figure 7] This is a structural diagram schematically showing another embodiment in which the method of reducing frictional resistance of a ship body according to this invention is applied to a vessel.

[Figure 8] This is a perspective view schematically showing the constitution of the negative pressure forming section shown in Figure 7.

[Figure 9] This is a state diagram showing the relationship between the position of the negative pressure forming section shown in Figure 7 and the flow of water.

[Brief Description of the Reference Symbols]

M, M2	friction reducing ship
1, 10	ship body
2, 40	flow of water
3, 20, 54	negative pressure forming section
4, 41	negative pressure region
5, 21	fluid passage
7, 43	gas/liquid interface (boundary surface)
11, 50	bubble generation apparatus
12	ship body outer hull (submerged surface)
15	water surface (waterline)
30	wing
31, 32	struts
33	fluid guiding body
33b	curved surface

33c	discharge opening
34, 67	water passage
35	air induction pipe
37	air intake opening
42	bubbles
51	outer pipe
52	inner pipe
53	position adjusting section

[Table 1]

Force component	Factor to which magnitude of force is proportional
resistance force (viscous force)	velocity raised to second power, surface area
pressure gradient force	surface area
lift force	vorticity, velocity
buoyant force	volume
volume change force	volume
additional inertial force	acceleration
surface tension	radius raised to the -1 power

[Document Type] Abstract

[Abstract]

[Problem] To provide a method of reducing frictional resistance of a ship body, and a friction reducing ship, in which it is possible to effectively reduce the energy consumption during cruising by carrying out reduction of frictional resistance at a low energy consumption.

[Means for Solving the Problem] A method of reducing the frictional resistance of a ship body by ejecting bubbles on a submerged surface 12 of a ship body 10 forms a negative pressure region 41 in the water having a pressure lower than that in a gaseous space resulting from cruising of the ship body 10 in the water, directs a gas from the gaseous space to the negative pressure region 41 in the water, and forms a flow of water 40 having locally large vortices.

[Elected Drawing] Figure 1

FIG. 1

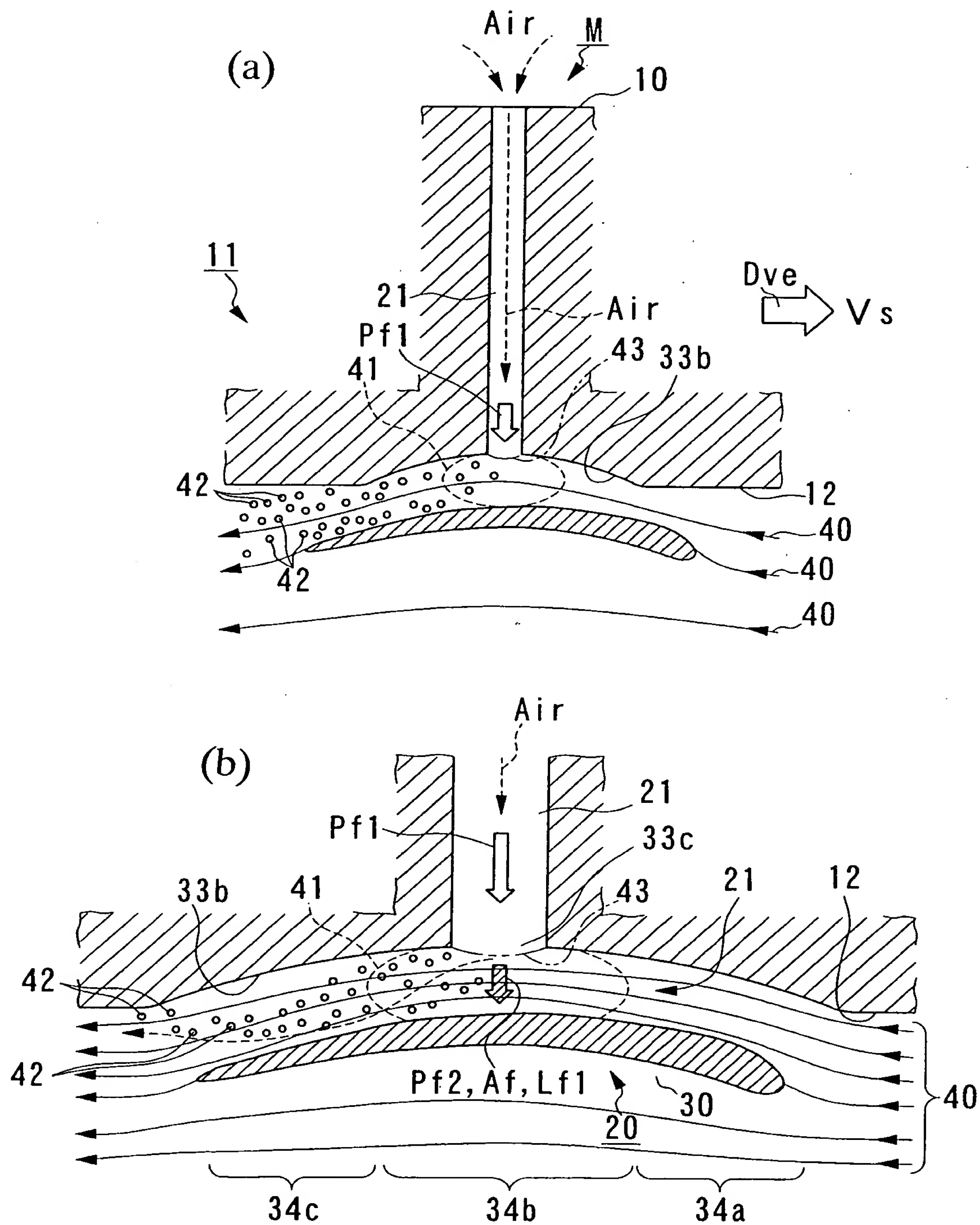

(a)
Air
M
10
11
21
Air
Dve
Vs
Pf1
41
43
33b
42
12
40
40
42
40
(b)
Air
21
Pf1
33c
33b
41
43
21
12
42
42
Pf2, Af, Lf1
30
40
20
34c
34b
34a

FIG. 2

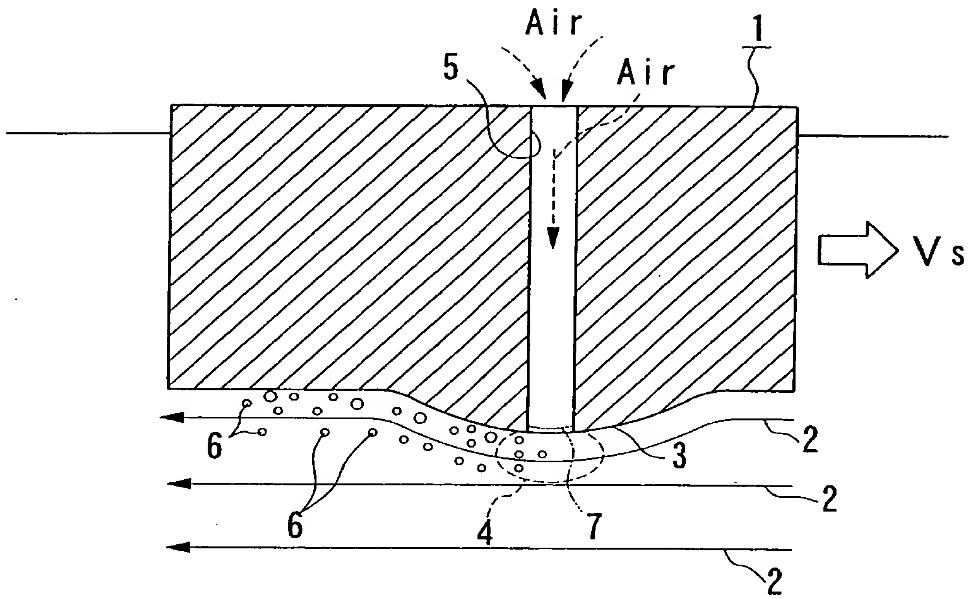

Air
Air
1
5
Vs
6
6
2
3
2
4
7
2

FIG. 3

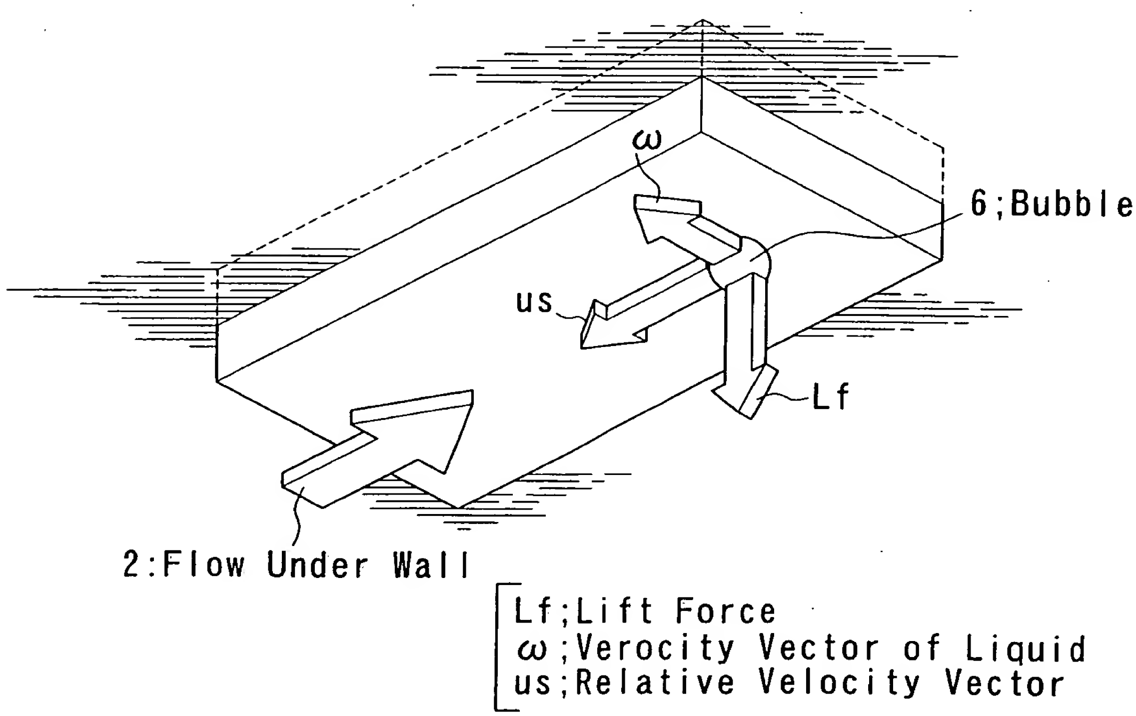

ω
6;Bubble
us
Lf
2:Flow Under Wall
Lf;Lift Force
ω;Verocity Vector of Liquid
us;Relative Velocity Vector

FIG. 4

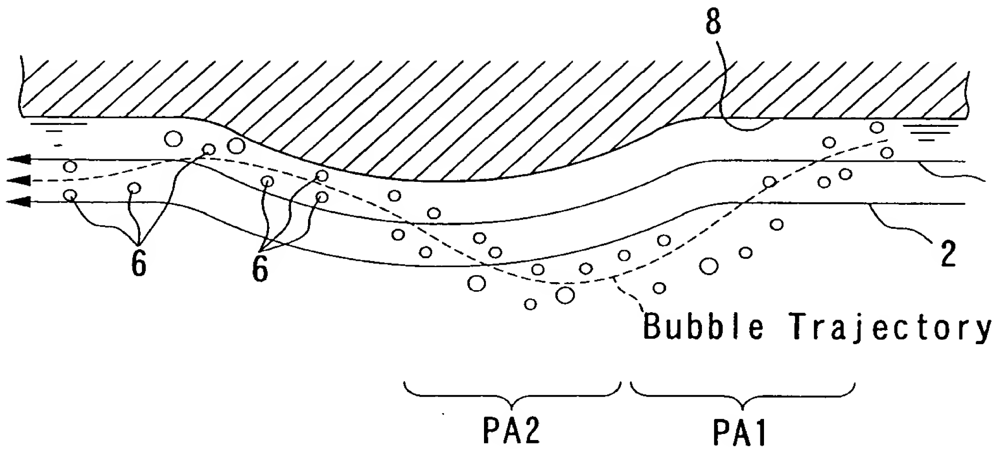
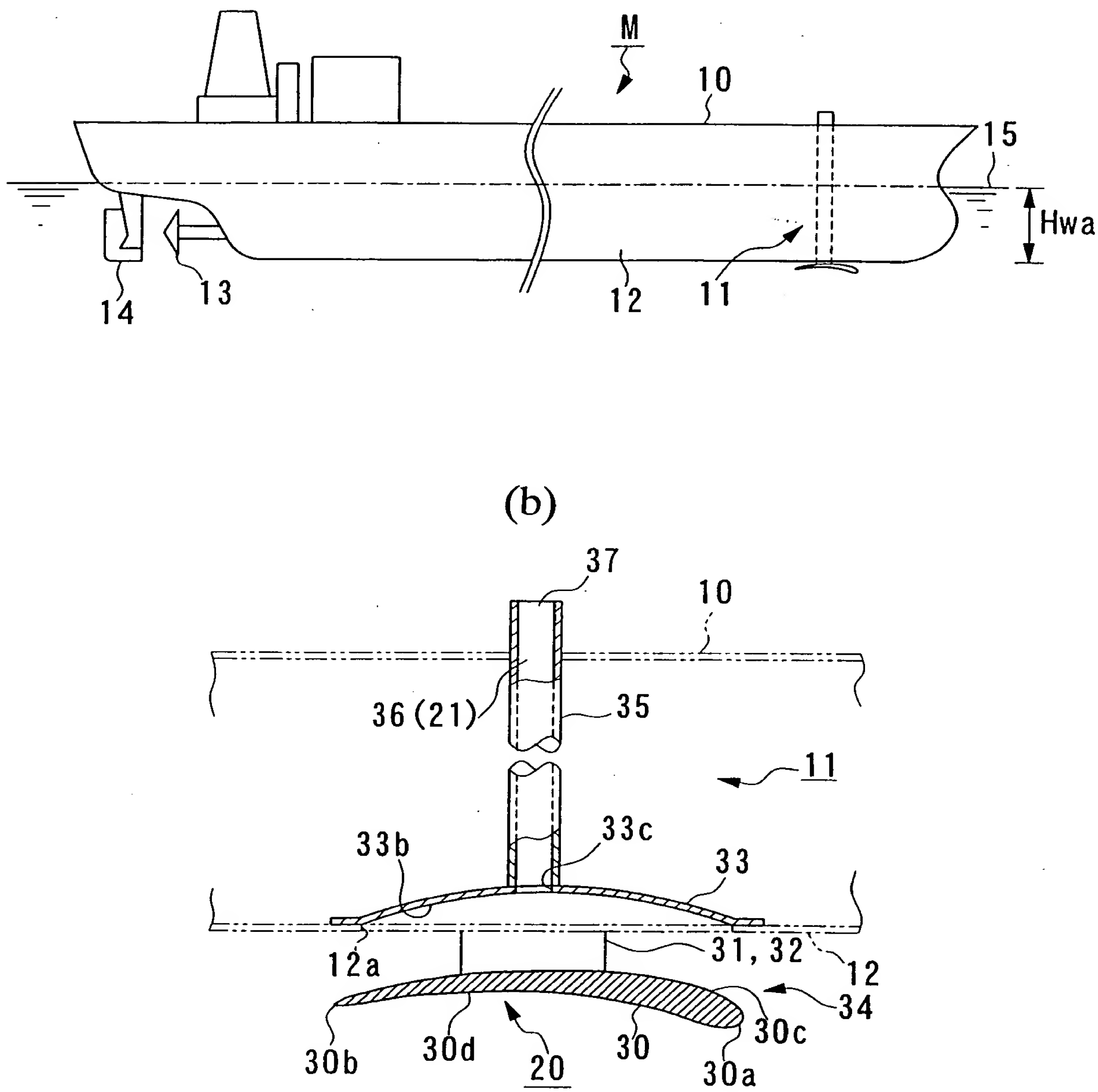


FIG. 5

(a)


M
10
15
Hwa
14
13
12
11

(b)

37
10
36 (21)
35
11
33b
33c
33
12a
31, 32
12
34
30b
30d
20
30
30c
30a

FIG. 6

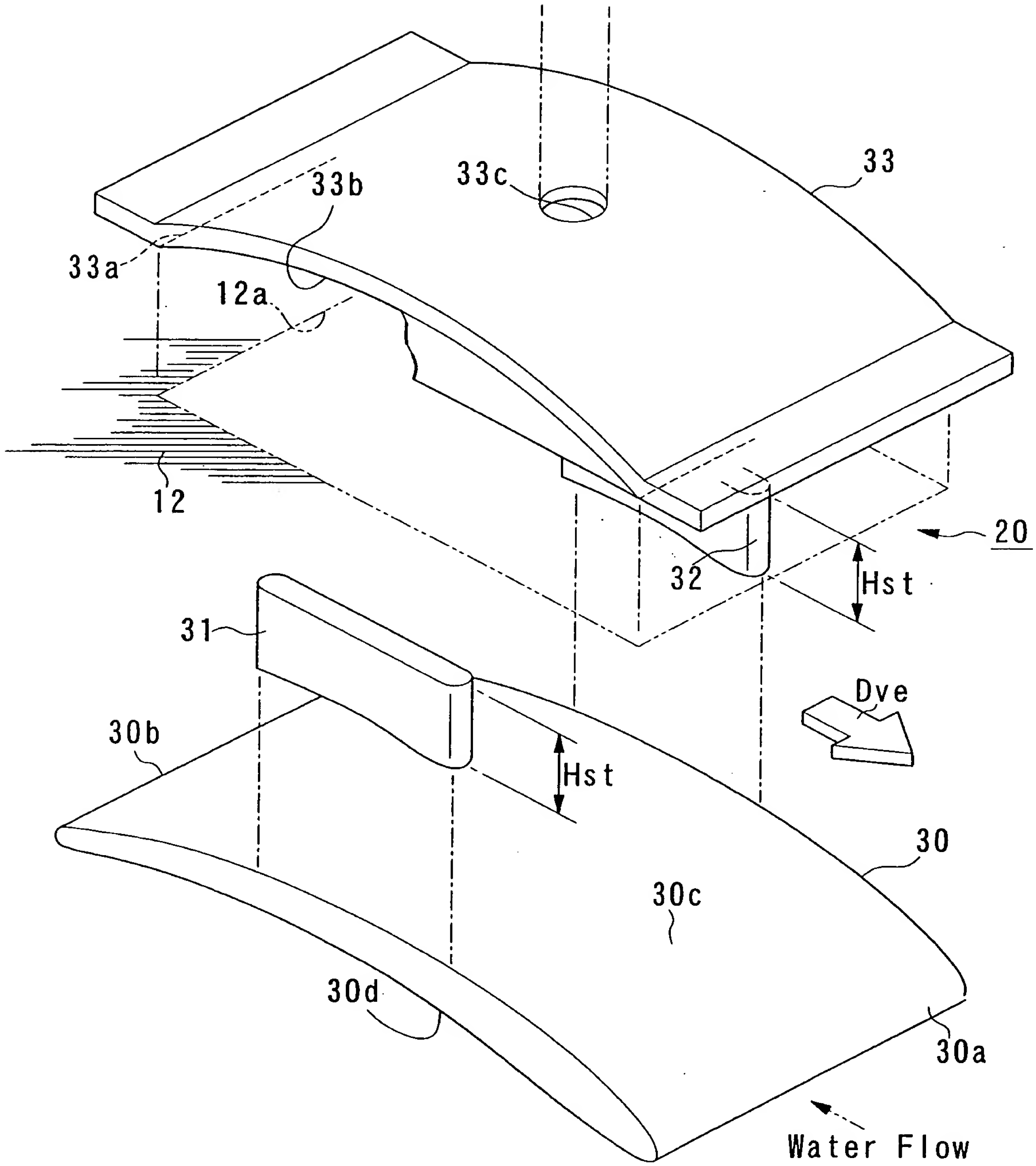

33c
33
33b
33a
12a
12
20
32
Hst
31
Dve
30b
Hst
30
30c
30d
30a
Water Flow

FIG. 7

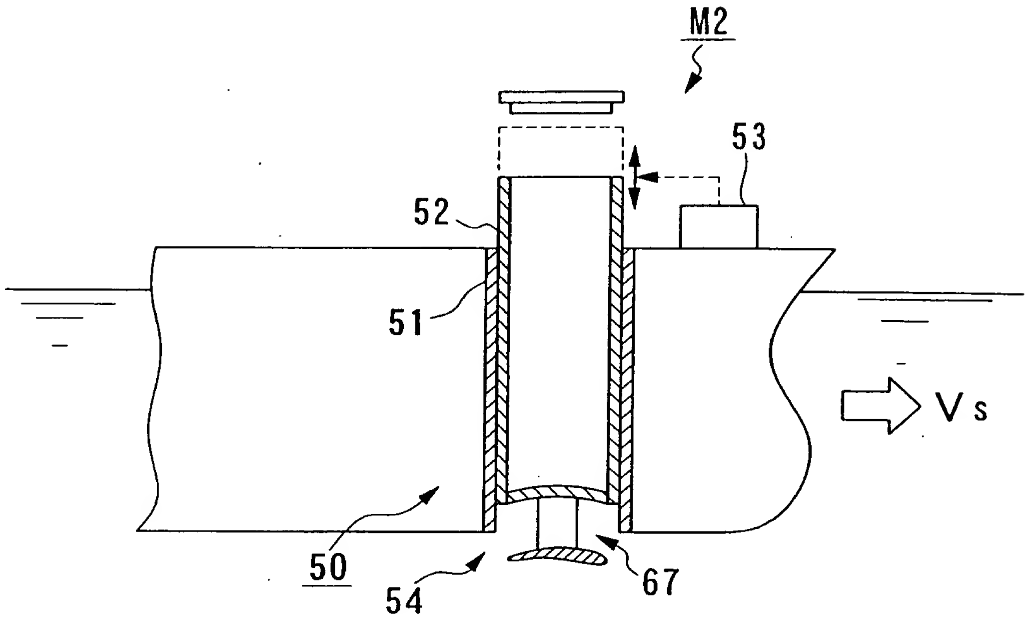


FIG. 8

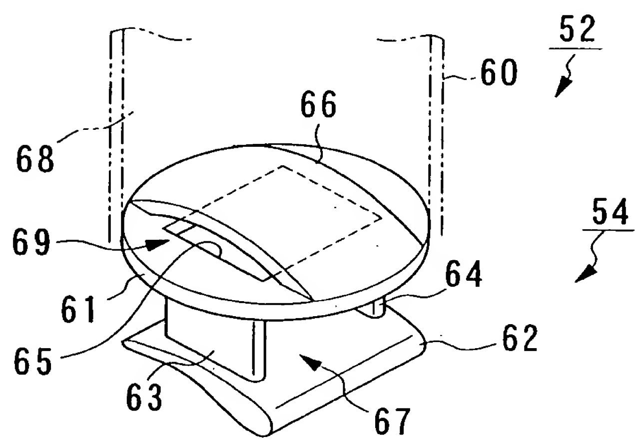


FIG. 9